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⑯ Applicant: MEDTRONIC, INC.  
3055 Old Highway Eight  
Minneapolis Minnesota 55440(US)

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⑯ Inventor: Cahalan, Patrick T.  
129 W. Eagle Lake Drive  
Maple Grove Minnesota 55369(US)

⑯ Designated Contracting States:  
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⑯ Inventor: Perrault, James J.  
1707 69th Avenue North  
Brocklyn Center Minnesota 55430(US)

⑯ Inventor: Jevne, Allan H.  
1314 153rd Lane N.E.  
Anoka, Minnesota 55303(US)

⑯ Representative: Schwan, Gerhard, Dipl.-Ing.  
Eiffenstrasse 32  
D-8000 München 83(DE)

⑰ Electrically conductive compositions and electrodes utilizing same.

⑰ Electrically conductive compositions particularly useful for biomedical electrodes wherein the conductive composition comprises the physical and electrical interface between the electrode and the skin of a subject. The conductive composition is conformable, flexible, adhesive and forms a cohesive body (12) readily adaptable to use at the interface area of the electrode (10). The compositions comprise an interpenetrating polymer network consisting essentially of a hydrophylic crosslinked polymer formed from a water soluble monomer and a hydrophylic, polymer which is not crosslinked, a humectant, and water.

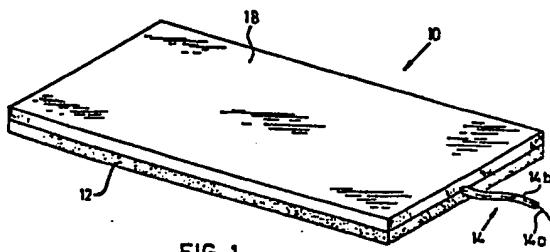


FIG. 1

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ELECTRICALLY CONDUCTIVE COMPOSITIONS AND  
ELECTRODES UTILIZING SAME

I. DESCRIPTION

Background of Prior Art

5        This invention relates to electrically conductive compositions per se and electrodes utilizing the compositions as a conductive interface. More particularly, the invention relates to biomedical electrodes utilizing the conductive compositions  
10      described herein for establishing electrical contact with the skin of a subject. Consequently, in its preferred embodiments, this invention is directed to medical electrodes for application to the skin. Skin electrodes are of varying types and may be used either  
15      as transmission electrodes or as sensing or monitoring electrodes. A wide variety of design configurations have been provided in the past for these kinds of electrodes, all of which are applicable to this invention.

20      A variety of electrically conductive compositions for biomedical electrodes is known in the art. Generally, they comprise pastes, creams or gels which are relied upon to conduct electric current and improve or establish the electrical connection between the skin of a subject and the electrode per se. Hydrogels have  
25      been particularly popular for the conductive composition. Some hydrogels are even self-adhesive in that they are inherently tacky.

30      None of the known compositions is completely satisfactory from all standpoints i.e., as to electrical conductivity, adhesiveness, cohesiveness, flexibility, etc.

35      The electrically conductive compositions of this invention are more satisfactory overall than the prior art compositions. Additionally, they do not tend to dry out as readily. They are based on a unique polymer

configuration known as an interpenetrating polymer network. Such networks have not been considered heretofore for use in forming conductive compositions, particularly in the preferred use herein i.e., biomedical electrodes.

For purposes herein, an interpenetrating polymer network is a combination of two polymers in network form, which occupy a specific volume and provide a single phase but are essentially not connected by primary chemical bonds. The networks referred to herein are prepared by synthesizing a crosslinked polymer from a water soluble monomer in the presence of an aqueous solution of a water soluble polymer, the first polymer being present in a predominant amount in the resultant interpenetrating polymer network relative to the amount of the second polymer.

Additional information concerning interpenetrating networks may be found in the article "Interpenetrating Polymer Networks: Now Thermoplastic" by L.H. Sperling, published in Modern Plastics, October, 1981, the content of which is hereby incorporated by reference.

The term "conformable" as used herein refers generally to the flexibility of the bulk conductive compositions or materials of the invention. The materials must be sufficiently flexible to conform to the surface of the skin or the like to which they or the electrode is attached and to provide a high surface area of contact to the skin or the like.

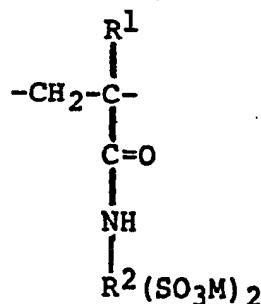
The term "cohesive" refers to the internal integrity of the conductive compositions or materials. Generally, the conductive material is self-supporting and must have more cohesive strength than adhesion to the skin or the like so that, when the electrode is removed from the skin or the like, the conductive material remains intact and does not leave an objectionable residue on the skin.

Summary of the Invention

The conductive compositions of the invention essentially comprise an interpenetrating polymer network including a hydrophylic, crosslinked polymer, preferably of an N-sulfohydrocarbon-substituted acrylamide, and an organic, hydrophilic, non-crosslinked polymer blended with a humectant and water. Preferably, the molecular weight of this polymer will be about at least 1800, about 5000 or 5100 being especially convenient, but molecular weight is not critical and may vary over a wide range.

Two of the essential components of the compositions of the invention form the required interpenetrating polymer network (IPN). These constituents are the aforementioned polymers.

The first polymer or polymeric constituent is at least one (usually only one) hydrophylic, crosslinked polymer, preferably of an N-sulfohydrocarbon-substituted acrylamide of the type described in U.S. Patent 4,136,078, which is incorporated herein by reference. These polymers contain at least one polymer unit represented by the formula:



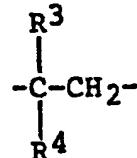
in which  $\text{R}^1$  is hydrogen or a lower (as defined herein-after) alkyl group and  $\text{R}^2$  is a divalent or trivalent hydrocarbon group. As used herein, the term "hydrocarbon group" includes aliphatic, cycloaliphatic and aromatic (including aliphatic and cycloaliphatic-

substituted aromatic and aromatic-substituted aliphatic and cycloaliphatic) groups. It also includes cyclic groups wherein the ring is completed through another portion of the molecule; that is, any two indicated 5 substituents may together form a cyclic hydrocarbon group.

Substituted hydrocarbon, alkylaryl, alkylene, arylene, etc., groups are considered fully equivalent to the hydrocarbon, alkyl, aryl, alkylene, arylene, etc., 10 groups and to be part of this invention. By "substituted" is meant groups containing substituents which do not alter significantly the character of reactivity of the group.

Preferably, the hydrocarbon or substituted hydro- 15 carbon groups in the N-sulfohydrocarbon-substituted acrylamides are free from ethylenic and acetylenic unsaturation and have no more than about 30 carbon atoms, desirably no more than about 12 carbon atoms. Lower hydrocarbon groups are particularly preferred, 20 the word "lower" denoting groups containing up to seven carbon atoms. Still more preferably, they are lower alkylene or arylene groups, most often alkylene.

In the formula, M is hydrogen or one equivalent of a cation and is usually hydrogen or an alkali metal. 25 R<sup>1</sup> is hydrogen or lower alkyl as already defined, but is preferably hydrogen or methyl, usually hydrogen. R<sup>2</sup> may be any divalent or trivalent hydrocarbon group, preferably lower alkylene or arylene and usually lower alkylene. In a preferred embodiment of this invention, 30 R<sup>2</sup> is



35

wherein R<sup>3</sup> is hydrogen or a lower alkyl group, R<sup>4</sup> is a

lower alkyl group and the sulfonic acid group is attached to the unsubstituted methylene carbon. These polymers may be obtained by the polymerization, either alone or in combination with other polymerizable vinyl monomers, of the corresponding monomeric N-sulfohydrocarbon-substituted acylamides of which the following acids, and their salts, are examples.

5 2-Acrylamidoethanesulfonic acid  
 $\text{CH}_2=\text{CHCONHCH}_2\text{CH}_2\text{SO}_3\text{H}$

10 2-Acrylamidopropanesulfonic acid



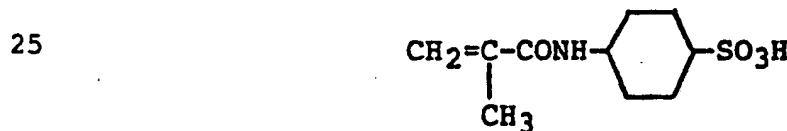
15 2-Acrylamido-2-methylpropanesulfonic acid  

$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_2=\text{CHCONHC}-\text{CH}_2\text{SO}_3\text{H} \\ | \\ \text{CH}_2 \end{array}$$

20 3-Methacrylamidopropanesulfonic acid



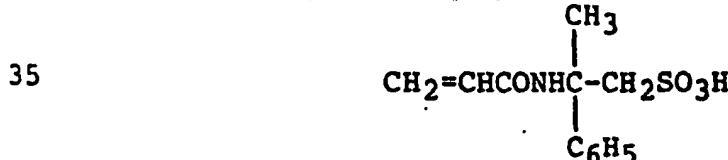
4-Methacrylamidocyclohexanesulfonic acid



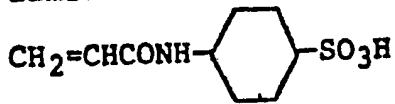
2-Acrylamido-2-phenylethanesulfonic acid



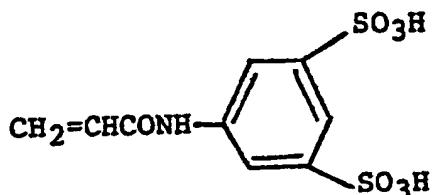
2-Acrylamido-2-phenylpropanesulfonic acid



## 4-Acrylamidobenzenesulfonic acid



## 5-Acrylamidobenzene-1,3-disulfonic acid



From the standpoint of economy, ease of preparation and polymerization, and effectiveness, the most desirable polymers are those of 2-acrylamido-2-methylpropanesulfonic acid or its salts. The term "N-sulfohydrocarbon-substituted acrylamide" when used hereinafter will refer to this class of compounds generally, with the understanding that the above named acid and its salts, particularly the sodium and potassium salts are especially preferred.

The N-sulfohydrocarbon-substituted acrylamide polymers used in the compositions of this invention may be homopolymers or copolymers, the latter containing at least about 5% by weight, and preferably at least about 20 50%, of N-sulfohydrocarbon-substituted acrylamide units. The identity of the other monomer or monomers is not critical except that the polymer must be water-soluble or capable of forming a stable aqueous suspension. The most useful polymers are homopolymers (which are preferred) and copolymers with about 5-95%, preferably about 5-50% and most desirably about 5-30%, of an unsaturated acid (e.g., maleic acid) or a derivative thereof, especially an acrylic monomer such as acrylic or methacrylic acid or a salt or amide thereof, notably acrylamide, methacrylamide, N-methylacrylamide, diacetone acrylamide and the like.

The N-sulfohydrocarbon-substituted acrylamide

polymer is prepared in aqueous solution. The polymerization may be promoted by typical initiators used in aqueous systems, especially peroxides, persulfates, persulfate-bisulfite and the like. The alkali metal 5 salts of 2-acrylamido-2-methylpropanesulfonic acid may be polymerized in the absence of polymerization initiator.

It is sometimes advantageous to carry out the polymerization in the presence of a small amount of chain 10 transfer agent, which tends to cause formation of a polymer with more uniformity in molecular weight than is otherwise produced. Suitable chain transfer agents are known to those skilled in the art.

Preferably, the first polymeric constituent will 15 possess inherent tackiness, as do the N-sulfohydrocarbon-substituted acrylamides, but this is not necessary. Examples of other polymers which may be used as the first polymeric constituent are: hydroxymethylmethacrylate and potassium acrylate polymers.

20 The second polymeric constituent of the compositions and of the interpenetrating polymer network of this invention comprises an organic, non-cross-linked, hydrophilic polymer which possesses inherent tackiness. The most preferred non-crosslinked polymer 25 of this type is polyacrylic acid, available commercially as an aqueous 50% solution GOODRITE<sup>®</sup> K-732. Other examples of polymers useful as the second polymeric constituent are: polyvinylpyrrolidone, and the various N-sulfohydrocarbon-substituted acrylamide polymers referred to above in non-crosslinked form.

30 The inclusion of the tacky non-crosslinked, hydrophilic second polymer constituent in the interpenetrating polymer network provides the tacky quality of the compositions of the invention along with any tackiness which may be provided by the first polymeric 35 constituent. Preferably, however, the first polymeric

constituent is also tacky as already pointed out.

As already indicated, the interpenetrating polymer network is formed by polymerizing and crosslinking the first polymeric constituent in the presence of the 5 second polymeric constituent, as is described in detail hereinbelow.

In addition to the interpenetrating polymer network formed by the first and second polymeric constituents as described above, the compositions of the invention 10 also essentially include a humectant. Applicable and preferred humectants include glycerol, propylene glycol, sorbitol, polyethylene glycol. Other non-volatile alcohols may be used as the humectant. The only requirement of the humectant is that it be compatible 15 with the material and that it maintain a range of moisture content such that the stated properties of adhesiveness, conformability and conductivity be maintained.

The balance of the compositions of the invention 20 essentially comprise water which need not be distilled or deionized or the like although that is preferred. Any water is acceptable although it should at least be potable for medical uses. Ordinarily, the water content of a composition according to the invention will 25 be on the order of about 12 to 45% by weight after the composition has been prepared and dried. During preparation in a preferred way, the water content is deliberately arranged to be higher for ease of preparation and is brought down to the desired range by drying, 30 preferably oven drying. Also, when exposed to high humidity conditions, the compositions will absorb water and may increase the content thereof to as high as 50%. Consequently, when water content is referred to herein, unless otherwise specified, the water content being 35 referred to is that of the composition as initially prepared and dried.

Generally, in preparing the compositions of the invention, the humectant and water may be included so as to be present during the formation of the interpenetrating polymer network.

5 The compositions of the invention will include the essential constituents in the following ranges (% by weight used throughout)

Interpenetrating polymer network (IPN) about 25-75%, about 55% preferred.

10 Humectant ---about 5-50%, about 30% preferred.

Water ----the balance.

As to the relative amounts of the two polymer constituents in the IPN, the first constituent is most preferably present from about 80% to about 90% and the 15 second constituent is most preferably present from about 10% to about 20%. However, generally speaking, the first constituent must be present in an amount of at least about 35% in the IPN, amounts greater than about 50% being more preferred.

20 As to the relative amounts of the two polymeric constituents in terms of the overall composition, it is preferred that the first polymeric constituent be present within the range of about 24% to 74%, about 45% preferred, the second being present within the range of 25 about 1% to 40%, about 10% preferred.

The compositions also include minor amounts of catalytic initiators which are insignificant as to the final properties of these compositions.

As is apparent to those skilled in the art, specific 30 minimum amounts and specific relative amounts of the constituents of the compositions of the invention will vary considerably depending on the specific constituents combined and the purpose for which the composition is to be used. In general, it is necessary 35 to select those amounts which will provide a cohesive, flexible, conductive, self-supporting, conformable body

of material suitable to a particular intended purpose.

In addition to the interpenetrating polymer network, humectant, water i.e., the essential constituents, and the various initiators, the compositions of this invention may contain other compatible ingredients which modify the characteristics thereof, e.g., by improving their remoistening ability, modifying their setting speed, and increasing their thermal stability. These additives may include fillers such as clay, chalk, fiberglass and carbon and antioxidants such as butylated hydroxyanisole, butylated hydroxytoluene and sodium benzoate, as well as others.

As already stated, for interface use with biomedical electrodes, the most preferred embodiment of the invention uses, as the crosslinked polymer of the interpenetrating polymer network, a salt of 2-acrylamido-2-methylpropanesulfonic acid, sodium, potassium and lithium salts being typical, the sodium salt being most readily available commercially at the present time. The preferred organic, non-crosslinked hydrophilic polymer is polyacrylic acid. The preferred humectant is glycerol.

Compositions including these constituents within the following ranges are preferred for biomedical electrode use (% expressed in terms of overall composition):

polymerized 2-acrylamido-2-methylpropanesulfonic acid or one of its salts, sodium salt most preferred about 24-74%, about 45% preferred

IPN% overall about 25%-75%

polyacrylic acid about 1-40%, about 10% preferred

glycerol about 5-50%, about 30% preferred

methylene bis-acrylamide cross-linking agent and initiators . . . up to about 5%, about 0.1% preferred

water . . . the balance

5 Brief Description of the Drawings

Fig. 1 is a schematic perspective view of an electrode according to the invention.

Fig. 2 is a plan view of the electrode of Fig. 1.

Fig. 3 is a cross-sectional view taken along line 10 3-3 of Fig. 2.

Fig. 4 is an elevational view of a preferred electrode.

Fig. 5 is a plan view of the electrode shown in Fig. 4.

15 Description of Specific Preferred Embodiments

The preferred usage of the compositions of the invention lies in their use as the interfacing material for biomedical electrodes. In this usage the compositions provide efficient and effective signal 20 transmission media between a subject's skin and various kinds of electro-medical apparatus.

The compositions of the invention and electrodes utilizing same are intended to possess inherent adhesive properties for maintaining contact with the skin 25 as well as possessing a certain amount of flexibility and conformability for movement with the skin in addition to a uniform configuration and homogeneity of composition for contact with the skin and the passage of uniform current densities to or from the skin. The 30 electrodes utilizing the compositions of the invention are easily handled, have an effective operating life without substantial drying out and are non-irritating

to the subject.

As previously pointed out, this invention particularly lends itself to medical electrodes of varying types, shapes and configurations. For exemplary purposes herein, a skin electrode 10 is shown in one of the common rectangular configurations.

5 Electrode 10 includes flexible, adhesive and conductive member 12 for contacting the skin. The composition of member 12 is in accordance with this 10 invention. An electrical lead means 14, including a conductive member 14a and an insulating sheath or covering 14b, electrically contacts member 12.

15 The embodiment of the electrode as shown in the Figures 1-3 also includes a support or backing 18, the chief purpose of which is to provide a protective and supportive member for the substrate. A preferred backing material is polyethylene foam. One such material is commercially available from Fasson, Inc., a division of Avery International of Paynesville, Ohio, 20 under the trade designation MED 416. The material is a four pound density cross-linked polyethylene foam coated with a tacky adhesive material of an acrylic type. The foam is 1/16th of an inch thick. However, various thicknesses may be used. The foam need not be 25 coated with the adhesive since it will in most instances, readily adhere to substrate 12 which, as previously pointed out, is inherently adhesive.

30 The preferred embodiment makes use of the adhesive coated foam as backing 18, the stainless steel foil current distribution member 16 and substrate member 12. The substrate member may be of various thicknesses, about .05 to .250 inches being preferred. Greater thicknesses may be used as dimension is not critical so long as the electrical resistance is not excessive for 35 the particular use involved.

In operation and use, electrode 10 is applied with

conductive substrate 12 in direct contact with the skin. The adhesive properties of substrate 12 eliminate the need for separate adhesive tape or any other separate securing measures to hold electrode 10 in continuous contact with the skin. Upon prolonged exposure or use, the substrate may be wiped with water or alcohol to increase its adhesiveness. Electrical signals either to or from the skin, depending on the type of electrode application desired, are conducted through substrate member 12, the current distribution member 16 and electrical lead means 14 including wire 14a. Preferably, wire 14a contacts distribution member 16 by being held between it and backing 18.

In a transmission type of arrangement, lead 14 receives electrical signals from an external apparatus (not shown). These signals are conducted into the current distribution member 16 which in turn conducts them into the conductive substrate 12. In this manner current densities are uniformly distributed over the area of substrate 12 and in turn uniformly transmitted to the skin surface in contact with substrate 12. In a sensing or monitoring arrangement, the flow of electricity is reversed in direction, originating at the skin and being conducted through the substrate 12, distribution member 16, lead wire 14a and to a suitable electro-medical monitoring apparatus (not shown).

Referring now to Figures 4 and 5, a preferred electrode configuration is shown. The electrode includes a conductive, carbon-filled silicone rubber support body 18 including a raised rib 18a contacted by an electrical lead 14. Attached to the bottom of body 18 is substrate 12 which comprises a composition of the invention. The composition is constituted so as to be adhesive, conductive, pliant, conformable and cohesive. Attachment is by the inherent adhesive quality of the composition.

Typically, about 50% carbon mixed with the silicone rubber will provide a suitable support body although this amount is not critical. Any amount providing a conductive body is generally satisfactory.

5 Other conductive fillers such as silver and the like may be used. Also, materials other than silicone rubber may be used such as any elastomer material which is either conductive inherently or which may be rendered conductive by filling.

10 Also, the support member 18 may be a thin flexible conductive material such as an aluminum or stainless steel foil or the like to which substrate 12 is directly attached, lead 14 then being attached to the foil member.

15 The composition of conductive substrate member 12 is unique to the invention, as already indicated. As previously stated, it includes an interpenetrating polymer network, preferably of polymerized 2-acrylamido-2-methylpropanesulfonic (AMPS) acid or one 20 of its salts and polyacrylic acid. In addition to the interpenetrating polymer network, the composition includes a humectant, preferably glycerol, and water so as to provide in preferred form a flexible sheet-like body. Crosslinked copolymers may also be used as the 25 first polymeric constituent to form the interpenetrating network. Copolymers may also be used as the second polymeric constituent. Additional polymeric thickeners and the like may be blended into the composition, although they are not ordinarily needed. The various 30 constituents are provided in such relative amounts as to form a flexible, self-supporting material with substantial shape retention which has adhesive properties and which is electrically conductive.

35 Preferably, the interpenetrating polymer network is formed by polymerizing and crosslinking 2-acrylamido-2-methylpropanesulfonic acid or one of its salts, most

preferably the sodium salt form, in the presence of non-cross-linked polyacrylic acid. The polymerization is carried out in aqueous solution in the presence of the humectant.

5        In the principle preferred embodiments, substrate member 12 comprises a sheet-like body of interpenetrating polymer network material formed from the sodium salt of 2-acrylamido-2-methylpropanesulfonic acid monomer purchased from the The Lubrizol

10      Corporation. The monomer upon being dissolved in water is readily polymerized. The preferred non-crosslinked polymer is polyacrylic acid dissolved in water. The preferred humectant is glycerol mixed in the aqueous solution in which polymerization and crosslinking of

15      the first polymeric constituent is carried out in the presence of the second polymeric constituent.

The following Examples are provided for illustration of the invention.

EXAMPLE I

20      140 mls of sodium 2-acrylamido-2-methylpropanesulfonate (NaAMPS) solution and 18 mls of GOODRITE<sup>®</sup> K-732 solution are mixed together. The Na AMPS solution comprises 35.70% Na AMPS, 21% glycerol and 0.76% methylene bis-acrylamide (MBA) (crosslinking agent), balance water. The GOODRITE<sup>®</sup> K-732 solution comprises 50% by weight polyacrylic acid in water. The molecular weight of the polyacrylic acid in GOODRITE<sup>®</sup> K-732 is 5100. The mixture is purged with nitrogen for about ten minutes following which catalytic initiators are added.

25      Preferred catalytic initiators comprise potassium meta-bisulfite solution (99.62% deionized water, 0.38% potassium meta-bisulfite) potassium persulfate solution (99.62% deionized water, 0.38% potassium persulfate) and ferrous sulfate solution (99.76% deionized water, 0.24% ferrous sulfate). The catalytic initiators are simultaneously injected, via individual 3 cc syringes

into the nitrogen purged agitated monomer solution. Upon addition of the initiators, the mixture is allowed to agitate for a short time, approximately ten seconds is satisfactory, then it is quickly poured into a tray 5 or other suitable mold in an enclosed nitrogen atmosphere. The solution polymerizes to a solid, tacky, clear gel like material in about 5 minutes following exotherm. The exotherm time is about  $90 \pm 15$  seconds.

10 Preferably, the tray or mold (7 3/4 X 12  $\frac{1}{2}$  inches used in this instance) into which the solution is poured will have the bottom thereof covered with a Mylar polyester sheet. Following polymerization the polymer body may then be readily removed from the mold 15 along with the Mylar<sup>®</sup> polyester sheet as a backing thereof.

The body is then dried with the Mylar in place in a forced air oven. For this particular example, drying at about 3 hours at 70°C is adequate.

20 The preparation described provides a sheet-like body 7 3/8 X 12 inches and about .060 inches thick having a composition after drying as follows (% in terms of overall composition):

25	Na AMPS	49.2%
	Polyacrylic acid	8.9%
	Glycerol	28.9%
	MBA (including initiators)	0.1%
	Water	12.9%

The volume resistivity of this material and all 30 other materials reported herein can be expected to fall below about 30,000 ohm-cm.

Example I represents the most preferred composition and the most preferred mode of preparation, utilizing prepared solutions which are mixed together. This 35 technique does not utilize heat activated catalysts, which may be used if desired. Non-heat activated cata-

lysts are preferred from a production standpoint.

Other modes of preparation are illustrated in some of the following Examples which do use heat activated catalysts.

5

EXAMPLE II

The following constituents were mixed together under ambient conditions. The mixture was poured into a mold. The mold was placed in a vacuum oven, deaerated and heated at a temperature of 65°C for about 10 4 hours. It was then placed in a forced air oven and dried at about 60°C to a weight of about 60 gms.

Mixture

	Hydroxyethylmethacrylate * (HEMA)	15 gms
	Polyvinylpyrrolidone (PVP)	24 gms
15	Glycerol	10 gms
	Water	50 gms
	2,2'-Azobis[2-methylpropionitrile] (AIBN)	0.02 gms
	*sold with 0.5-1.5% impurity ethyleneglycoldimethacrylate, a crosslinker.	

20

The composition of the resultant product is:

Final Composition

	HEMA	25%
	PVP	40%
	Glycerol	16.7%
25	AIBN	0.03%
	Water	18.27%

EXAMPLE III

Same as Example II with differences noted.

Mixture

	Potassium Acrylate	10 gms (57% solution in water)
5	GOODRITE <sup>®</sup> K-732	0.5 gms
	Glycerol	10 gms
	MBA	10 gms (1% solution in water)
	Ammonium persulfate (AP)	0.5 gms (2% solution in water)
	In preparation, this material was oven dried to a	
10	weight of 20 gms.	

Final Composition

	Potassium Acrylate	28.5%
	GOODRITE <sup>®</sup> K-732	1.2%
	Glycerol	50.5%
15	MBA	0.5%
	AP	0.05%
	Water	19.75%

EXAMPLE IV

Same as Example III with differences noted.

Mixture

	Na AMPS	150 gms (50% solution in water)
5	GOODRITE <sup>®</sup> K-732 (MW 1800) PAA)	9 gms (50% solution in water)
	Glycerol	5 gms
	MBA	50 gms (1% solution in water)
	AP	4 gms (2% solution in water)
10	Dried to 100 gms.	

Final Composition

	Na AMPS	75%
	GOODRITE <sup>®</sup> K-732 (PAA)	4.5%
	Glycerol	5%
15	MBA	0.5%
	AP	0.08%
	Water	14.92%

EXAMPLE V

Same as Example III with differences noted.

Mixture

Na AMPS solution as in Example I 50 mls

5 Carbopol 940 (tradename of B.F.  
Goodrich Co.) (PAA MW 4 million) 1.5 gms

AP 0.5 gms

Dried to 33 gms.

Final Composition

10	Na AMPS	51.9%
	PAA	4.5%
	Glycerol	30.5%
	MBA	1.0%
	AP	0.03%
15	Water	12.07%

EXAMPLE VI

Same as Example III with differences noted.

Mixture

Na AMPS	84 gms (50% solution in water)
5 Acrylamide (copolymer with Na AMPS)	40 gms
PVP	6 gms
Glycerol	40 gms
MBA	6 gms (1% solution in water)
AP	2 gms

10 No drying - as made.

Final Composition

Na AMPS	30.3%
Acrylamide	1.9%
PVP	4.3%
15 Glycerol	28.8%
MBA	0.04%
AP	0.03%
Water	34.63%

EXAMPLE VII

Same as Example III with differences noted.

Mixture

	Na AMPS solution as in Example I	10 gms
5	GOODRITE <sup>®</sup> K-732 (PAA)	2 gms
	MBA	40 gms (1% solution in water)
	AP	0.5 gms

Dried to 9.5 gms.

Final Composition

10	Na AMPS	37.6%
	PAA	10.5%
	Glycerol	22.1%
	MBA	5.0%
	AP	0.1%
15	Water	24.7%

EXAMPLE VIII

Same as Example III with differences noted.

Mixture

	Na AMPS	80 gms (50% solution in water)
5	Potassium Acrylate (copolymer with NaAMPS)	20 gms (57% solution in water)
	PVP	6 gms
	Glycerol	40 gms
	MBA	6 gms
10	AIBN	0.02 gms

Not dried - as made.

Final Composition

	Na AMPS	26%
	Potassium Acrylate	7.5%
15	PVP	3.9%
	Glycerol	26.3%
	MBA	0.04%
	AIBN	0.01%
	Water	36.25%

EXAMPLE IX

Same as Example III with differences noted.

Mixture

5      2-acrylamido-2-methylpropane-  
          sulfonic acid (AMPS)      80 gms (50% solution in water)

PVP                                    6 gms

Glycerol                            40 gms

MBA                                    6 gms (1% solution in water)

AP                                    0.4 gms (1% solution in water)

10      Not dried - as made.

Final Composition

AMPS	30.2%
PVP	4.5%
Glycerol	30.2%
15      MBA	0.045%
AP	0.003%
Water	35.052%

EXAMPLE X

Same as Example I with differences noted.

Mixture

	Na AMPS	85 gms (50% solution in water)
5	GOODRITE® K-732	15 gms (50% solution in water)
	Glycerol	25 gms
	MBA	9 gms (1% solution in water)
	Each catalyst in Example I	2 gms each
	NaCl	0.75 gms
10	Dried to 138 gms.	

Final Composition

	Na AMPS	30.8%
	PAA	5.4%
	Glycerol	18.1%
15	MBA	0.07%
	Catalysts	0.02%
	NaCl	0.54%
	Water	45.08%

EXAMPLE XI

Same as Example I with differences noted.

Mixture

	Na AMPS	85 gms (50% solution in water)
5	GOODRITE <sup>®</sup> K-732 (PAA)	20 gms (50% solution in water)
	Propylene glycol	15 gms
	MBA	2 gms
	Catalysts as in Example I	6 gms total

Not dried - as made.

10

Final Composition

	Na AMPS	29.7%
	PAA	7.0%
	Propylene Glycol	10.5%
	Glycerol	10.5%
15	MBA	0.014%
	Catalysts	0.014%
	Water	42.272%

As already pointed out, various additives may be included in the compositions of the invention, it only being necessary that the compositions include, in varying amounts, the essential interpenetrating polymer network with a sufficient amount of water and humectant to provide the requisite electrically conductive, conformable and flexible, cohesive, adhesive body.

Various body thicknesses of the compositions may be used as desired and any electrode configuration with or without backing support and current distribution member may be used. Release paper of the waxed, silicone-treated or plastic coated variety or Mylar polyester sheet may be included to protect the substrate material prior to use.

Electrodes utilizing these compositions or any other devices utilizing same or the compositions per se should be stored in a sealed container or under controlled conditions or humidity to prevent drying out.

Many changes in embodiments of the invention will become apparent to those of ordinary skill in this art without departing from the scope of the invention. The description herein is not intended to be limiting in any sense and the exclusive property rights claimed are defined hereinbelow.

WHAT IS CLAIMED IS:

Claims

1. An electrically conductive, adhesive, cohesive composition characterized by:  
5 an interpenetrating polymer network essentially including two components: a first polymeric constituent which is crosslinked and hydrophilic and a second polymeric constituent which is hydrophyllic and not crosslinked, the network being comprised of at least about 35% of the first constituent; humestant; and  
10 water.
2. The composition of claim 1 wherein the interpenetrating network is comprised of an amount of the first polymeric constituent in excess of about 50% and preferably between about 80% and 90%.
3. The composition of claim 1 or 2 wherein the interpenetrating polymer network comprises about 25% to 20 70% of the overall composition.
4. The composition of any one of the preceding claims wherein the amount of the humectant is about 5% to 50%.
5. The composition of any one of the preceding claims 25 wherein the first polymeric constituent is a hydroxymethylmethacrylate polymer.
6. The composition of any one of claims 1 to 4 wherein the first polymeric constituent is a potassium acrylate polymer.  
30
7. The composition of any one of claims 1 to 4 wherein the first polymeric constituent is an *N*-sulfohydrocarbon substituted acrylamide polymer.

8. The composition of any one of claims 1 to 4 wherein the second polymeric constituent is polyacrylic acid.
9. An adhesive, electrically conductive composition, characterized by essentially including between about 5 25% and about 75% of an interpenetrating polymer network formed as the result of the polymerization and cross-linking of 2-acrylamido-2-methylpropanesulfonic acid or one of its salts in the presence of a hydrophylllic polymer and including between about 5% to 10 about 50% of a humectant, the balance being substantially water.
10. The composition of claim 9 wherein a salt form of the 15 2-acrylamido-2-methylpropanesulfonic acid is polymerized.
11. The composition of claim 10 wherein the salt is a 20 sodium salt.
12. The composition of any one of claims 9 to 11 wherein the amount of the polymer network is about 50%.
13. The composition of any one of claims 9 to 12 wherein 25 the hydrophylllic polymer is polyacrylic acid.
14. The composition of claim 13 wherein the molecular weight of the polyacrylic acid is about 5,000.
- 30 15. The composition of any one of the preceding claims wherein the humectant is glycerol.
16. The composition of any one of claims 1 to 14 wherein 35 the humectant is propylene glycol, polyethylene glycol or sorbitol.

17. The composition of any one of the preceding claims wherein the amount of the humectant is about 30%.

18. An electrically conductive, adhesive, conformable and flexible, cohesive body, characterized by: an interpenetrating polymer network essentially including two components: polymerized and crosslinked 2-acrylamido-2-methylpropanesulfonic acid, its salts or copolymers of the acid or its salts as the first component and, as the second component, an organic, hydrophilic polymer, the amounts of the first component and the second component in terms of overall composition ranging from about 24% to 74% and 1% to 40%, respectively:

15 a humectant ranging in amount from about 5% to 50%, and

water, substantially the balance.

19. The body of claim 18 wherein the amounts of the two polymer network components are about 45% and 10%, respectively.

20. The body of claim 18 or 19 wherein the amount of the humectant is about 30%.

25 21. The body of any one of claims 18 to 20 wherein the amount of the interpenetrating polymer network is about 25% to 75% and preferably about 50%.

30 22. The body of any one of claims 18 to 21 wherein the first component is a polymerized salt of 2-acrylamido-2-methylpropanesulfonic acid.

23. The body of claim 22 wherein the salt is a sodium salt.

24. The body of any one of claims 18 to 23 wherein the second component is polyacrylic acid.
25. The body of claim 24 wherein the molecular weight of the polyacrylic acid is about 5,000.
26. An electrically conductive, adhesive, cohesive body, characterized in that the body is comprised predominately of an interpenetrating polymer network essentially including two polymer components: a cross-linked, hydrophilic polymer and a non-crosslinked, linear hydrophilic polymer and including in lesser amounts a humectant and water.  
10
27. The body of claim 26 wherein the interpenetrating polymer network is comprised of at least about 35% and preferably at least about 50% of the crosslinked polymer.  
15
28. The body of claim 27 wherein the amount is about 80% to 90% and the second component comprises substantially the balance of the network.  
20
29. The body of claim 14 wherein the humectant is glycerol.  
25
30. The body of claim 14 wherein the humectant is propylene glycol, sorbitol or polyethylene glycol.
31. An adhesive electrode for establishing electrical contact with a surface, comprising:  
30 support means and terminal means for connection to external electrical circuit means, and an adhesive, conductive body for electrically interfacing with the surface to be contacted, the body being contacted by the support means and being in electrical communication with the terminal means, characterized  
35

by the adhesive, conductive body comprising a composition of an interpenetrating polymer network essentially including two components: a first polymeric constituent which is crosslinked and hydrophilic and, a second polymeric constituent which is hydrophilic and not crosslinked, the network including at least about 35% of the first constituent; a humectant, and water.

10

32. The electrode of claim 31 wherein the composition includes as the two components: polymerized crosslinked 2-acrylamido-2-methylpropanesulfonic acid, its salts or copolymers of the acid or its salts as the first component and, as the second polymeric component, the overall amounts of the first and second components ranging from about 24% to 74% and 1% to 40%, respectively.

15

33. The electrode of claim 32 wherein the first component is a polymerized salt form of the 2-acrylamido-2-methylpropanesulfonic acid.

20

34. The electrode of claim 33 wherein the salt is a sodium salt.

25

35. The electrode of any one of claims 32 to 34 wherein the hydrophilic polymer is polyacrylic acid.

30

36. The electrode of claim 35 wherein the molecular weight of the polyacrylic acid is about 5,000.

37. The electrode of any one of claims 31 to 36 wherein the humectant is glycerol.

38. *The electrode of any one of claims 31 to 36 wherein the humectant is propylene glycol, sorbitol or polyethylene glycol.*

5 39. *The electrode of any one of claims 31 to 38 wherein the amount of the humectant is about 30%.*

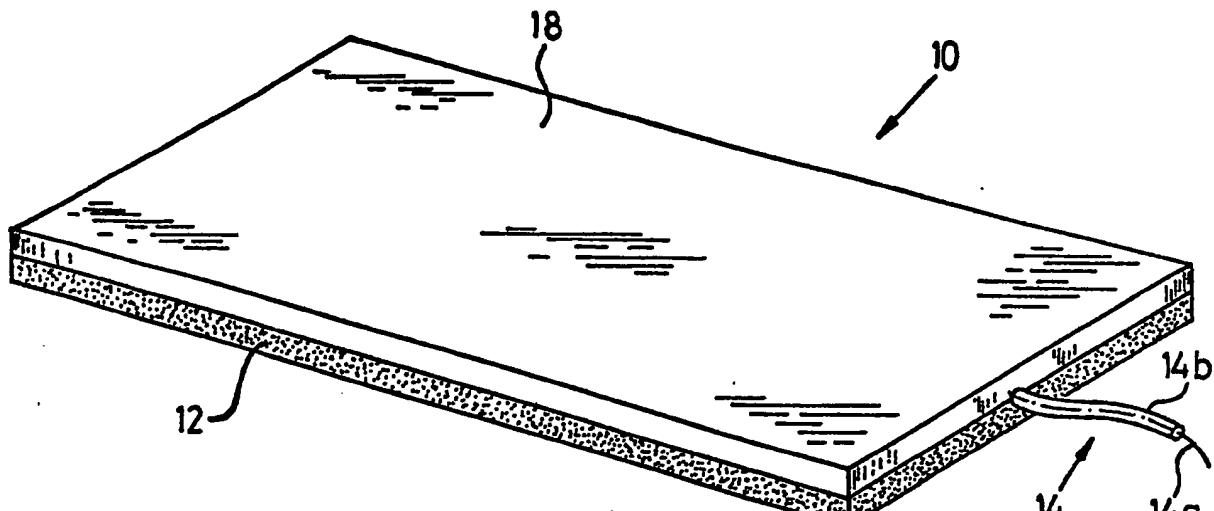


FIG. 1

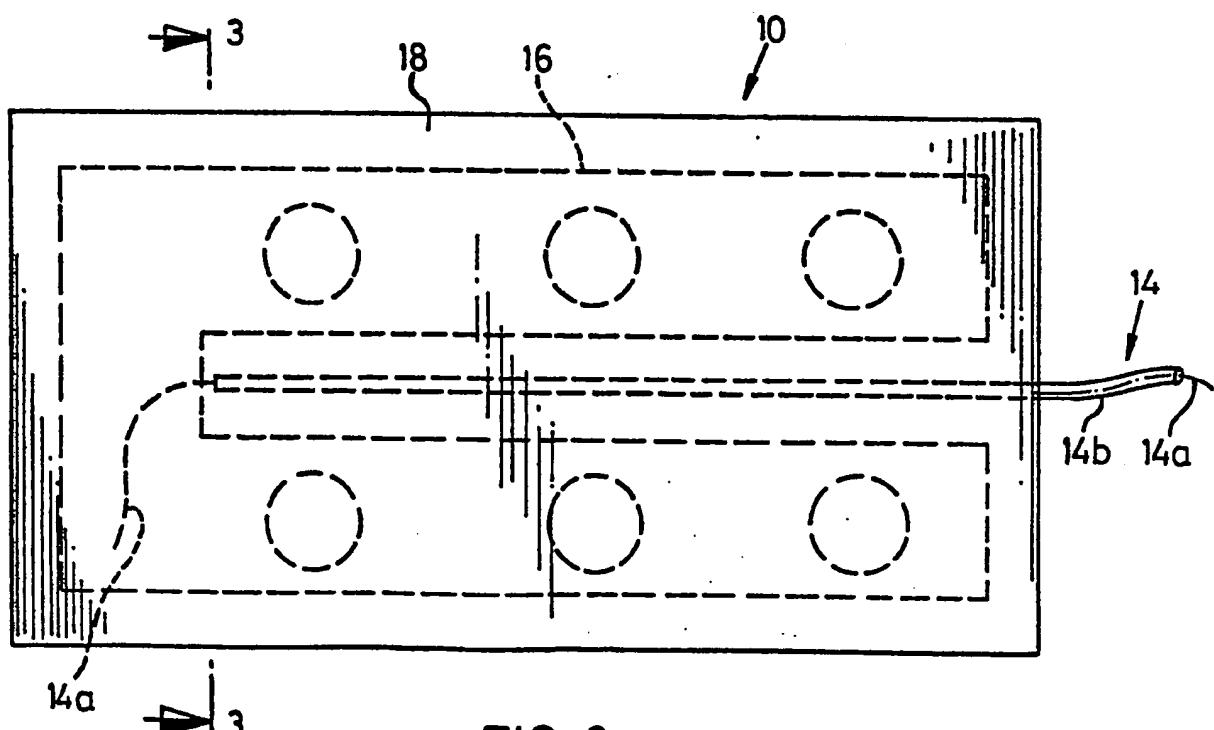
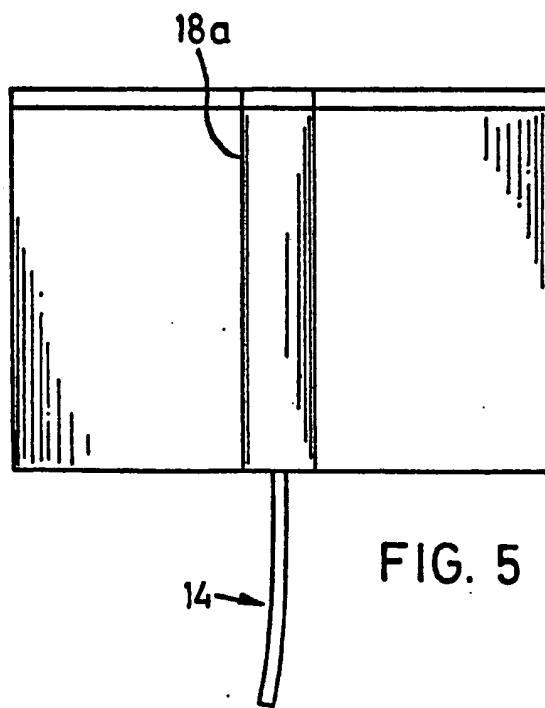
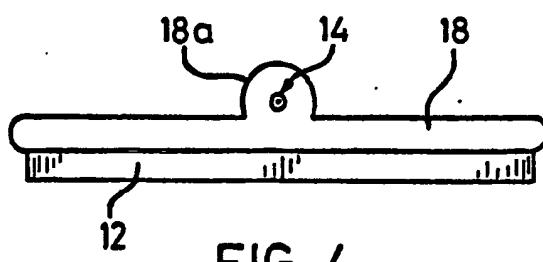
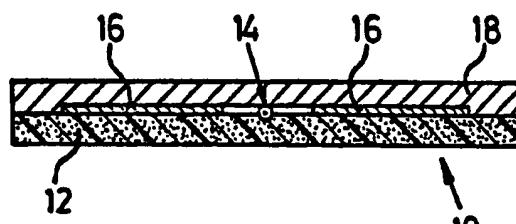


FIG. 2

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DOCUMENTS CONSIDERED TO BE RELEVANT			EP 83100323.1		
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 5)		
A	<p><u>EP - A1 - 0 012 402</u> (MEDTRONIC INC.)</p> <p>* Totality, especially claims 1-9; examples 12, 25; page 4, line 10 - page 5, line 7 *</p> <p>--</p>	1,4,7- 10,12, 13,15- 18,20, 22,24, 26,29- 33,35, 37-39	A 61 B 5/04 A 61 N 1/04 H 01 B 1/12 C 09 J 3/14		
A,D	<p>MODERN PLASTICS INT., October 1981, vol. 11, nr. 10, Lausanne</p> <p>L.H. SPERLING "Interpenetrating polymer networks: now thermoplastic", pages 68-71</p> <p>--</p>				
A	<p><u>WO - A1 - 81/02 097</u> (MINNESOTA MINING)</p> <p>* Page 5, line 30 - page 7, line 15 *</p> <p>--</p>	1,4-6, 15-17, 26,29- 31,35, 37-39	TECHNICAL FIELDS SEARCHED (Int. Cl. 5)		
A	<p><u>US - A - 4 066 078</u> (J. BERG)</p> <p>* Totality *</p> <p>--</p>	1,4,5, 8,15- 17,26, 29,30, 31,37- 39	A 61 B 5/00 A 61 B 17/00 A 61 N 1/00 H 01 B 1/00 C 09 J 3/00 C 08 J 3/00 C 08 K 5/00		
A	<p><u>US - A - 4 273 135</u> (F. LARIMORE, ST. HEILMANN)</p> <p>* Totality *</p> <p>--</p>				
A	<p><u>WO - A1 - 81/00 785</u> (MINNESOTA MINING)</p> <p>* Totality, especially claims 1,8,9 *</p> <p>--</p>	1,4,15, 16,31, 37,38, 39			
The present search report has been drawn up for all claims					
Place of search	Date of completion of the search	Examiner			
VIENNA	18-05-1983	LUDWIG			
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X : particularly relevant if taken alone	T : theory or principle underlying the invention				
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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A, D	<p><u>US - A - 4 136 078 (R. DOGGETT, H. BUCCIGROSS)</u></p> <p>* Totality *</p> <p>-----</p>		

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